Computer Models

EES 3310/5310
Global Climate Change
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Class #16: Wednesday, February 12 2020

Midterm Exam

- In class next Wednesday (Feb. 19)
- Bring #2 pencils, eraser, and calculator
- Test will provide important numbers and equations:
- You need to know how to tell:
    - which equations, numbers to use,
    - how to interpret them.
- Mostly conceptual questions, not so many with math
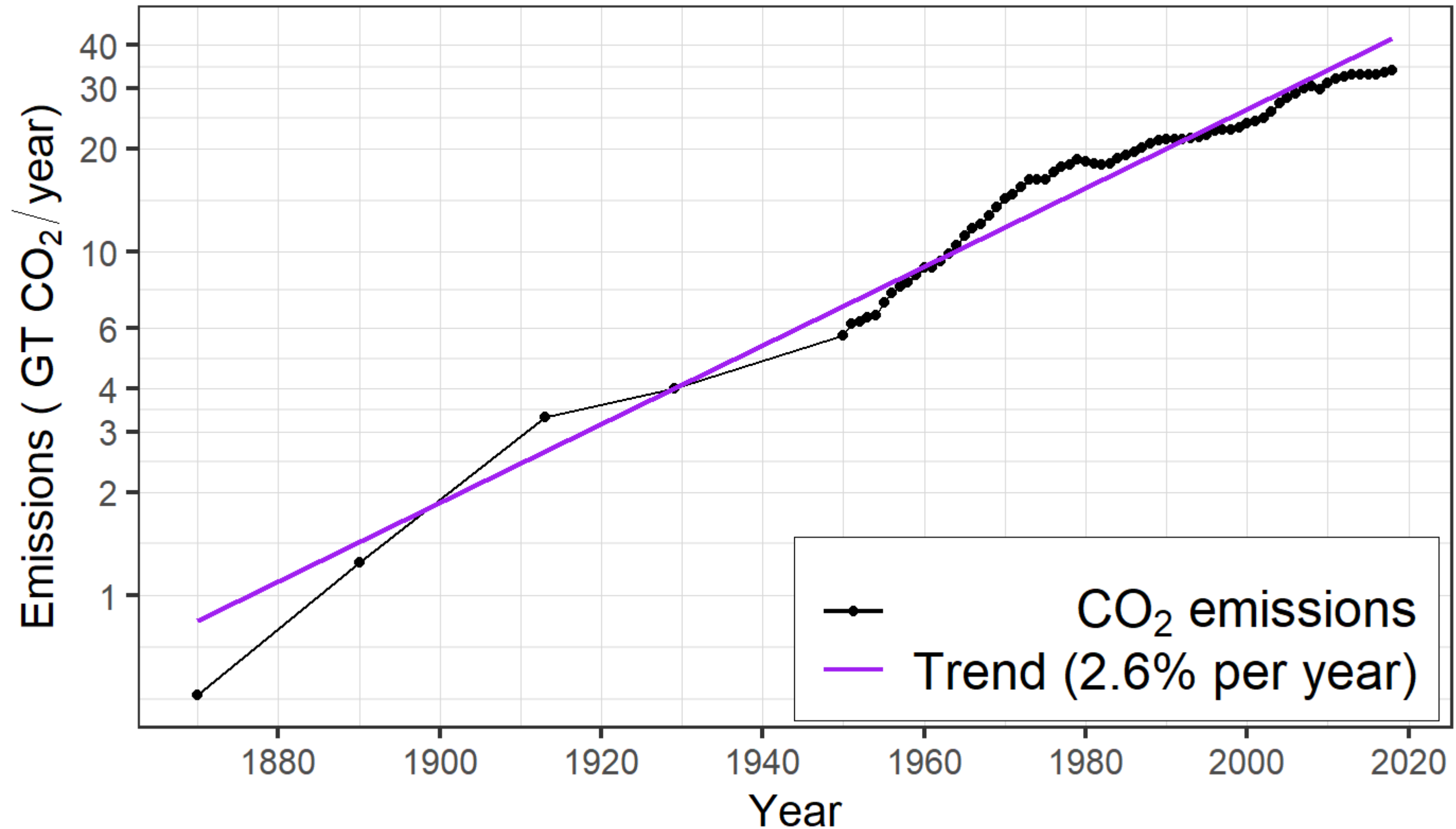- Practice test with answers will be posted on Brightspace

Climate and Economy

Climate and Economy
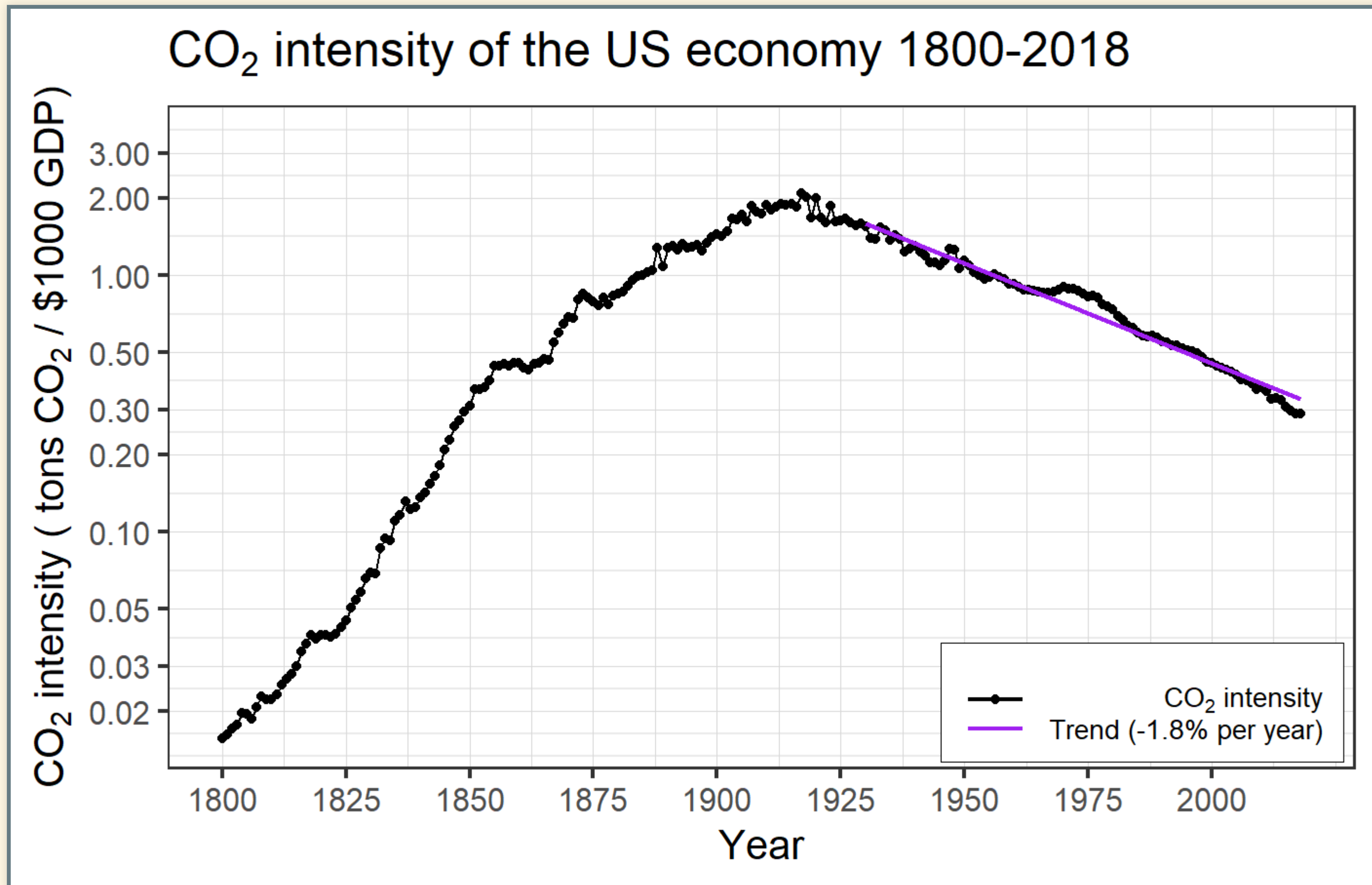## How well do markets manage global warming?

- How well do markets manage supply and price of bread?
- What is different about global warming?
- Externalities:
    - What is an externality?
    - Are externalities good or bad?
    - What challenges to they pose for markets?
    - How can market-based economies manage externalities better?

Energy, Economy, Emissions

Global CO_2 emissions 1870-2018

Emissions (GT CO_2 / year)

Year

CO_2 emissions

Trend (2.6% per year)

Energy, Economy, Emissions

CO$_2$ intensity of the US economy 1800-2018

Kaya Identity

Kaya Identity

$$P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} = F,$$

where

$F = CO_2$ emissions

$E =$ energy use

$G =$ gross domestic product

$P =$ population

Kaya Identity

$$F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E}$$

$$= P \times g \times e \times f$$
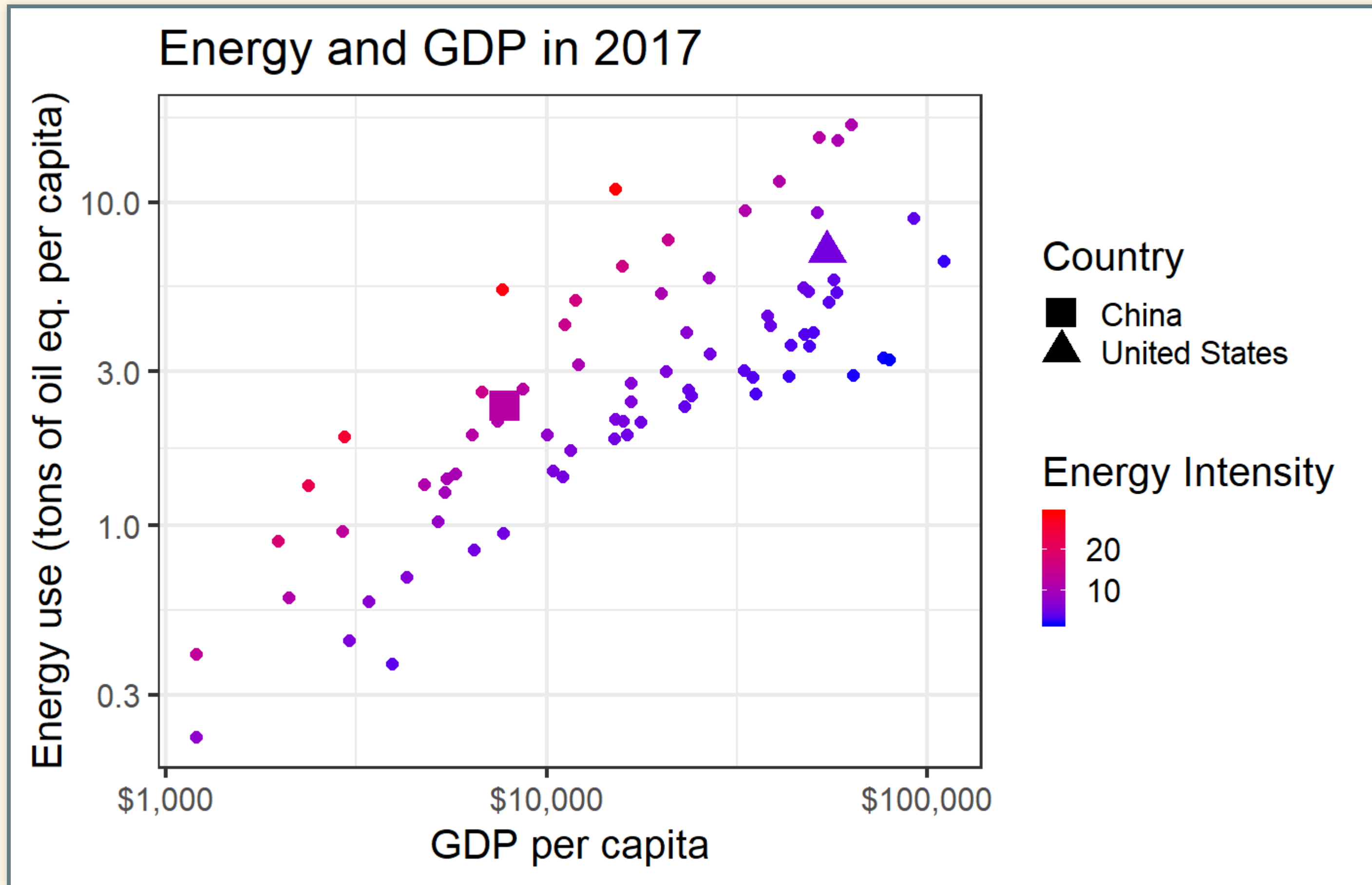
where

$P =$ population

$g = G/P =$ per-capita GDP
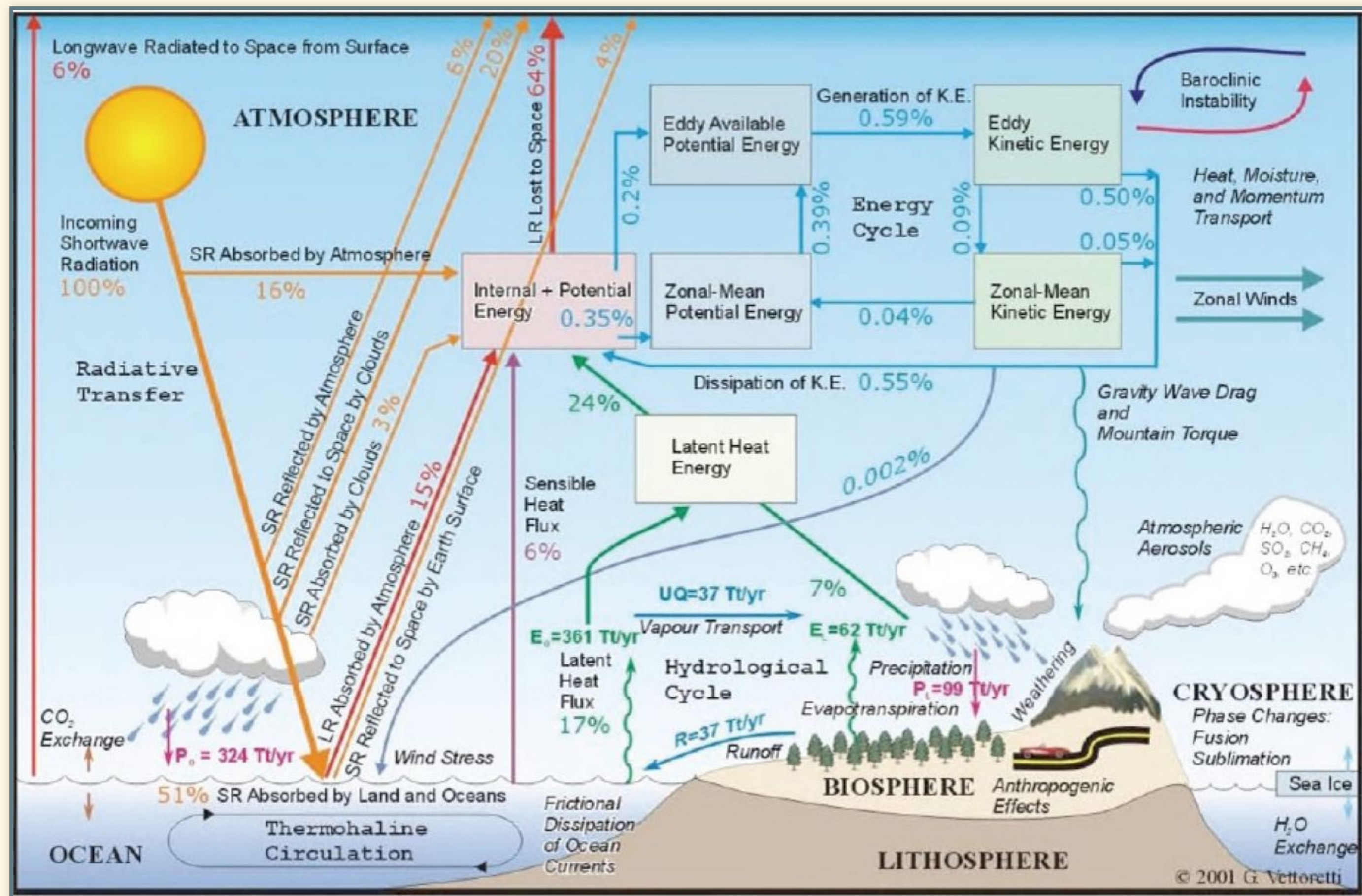
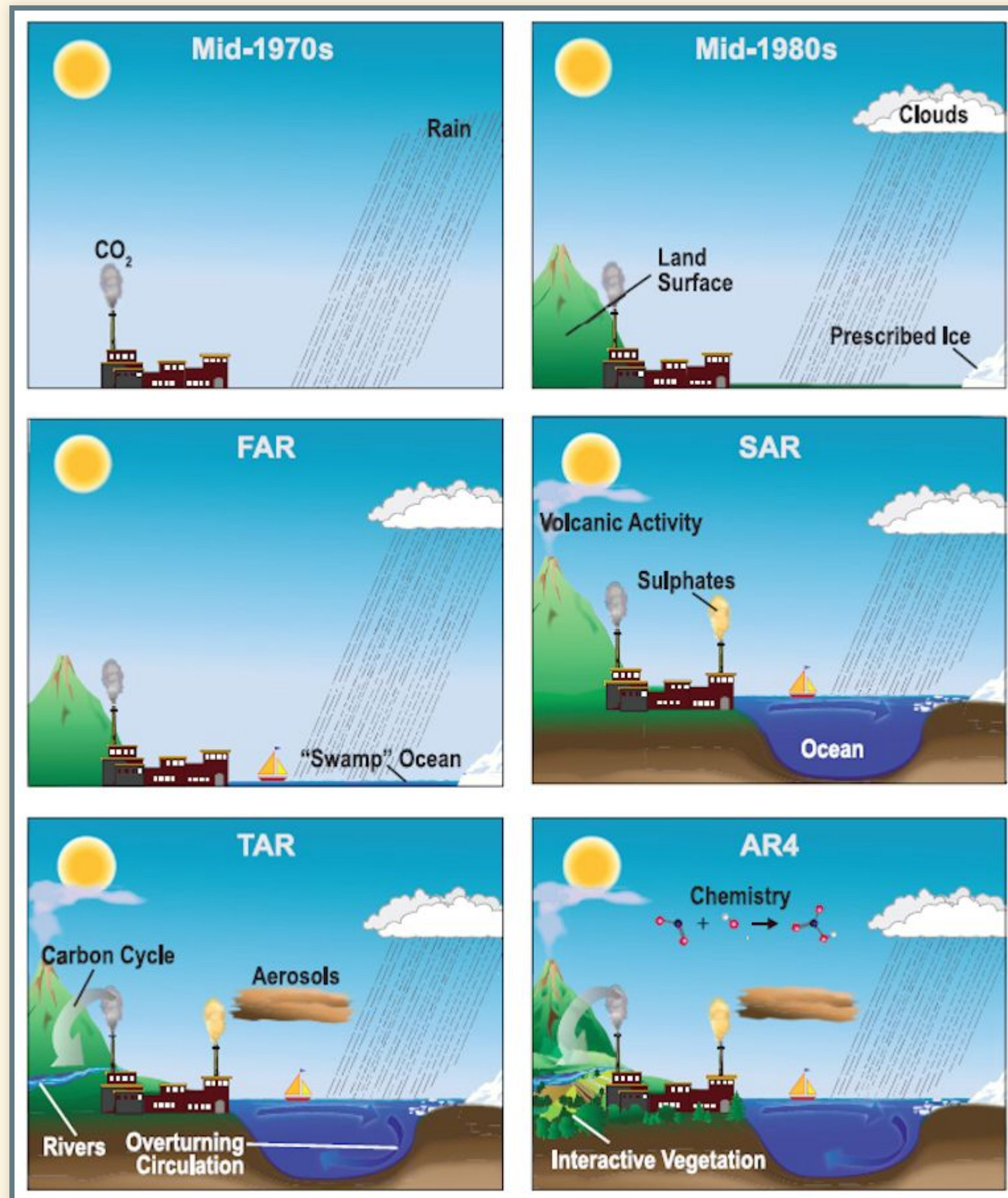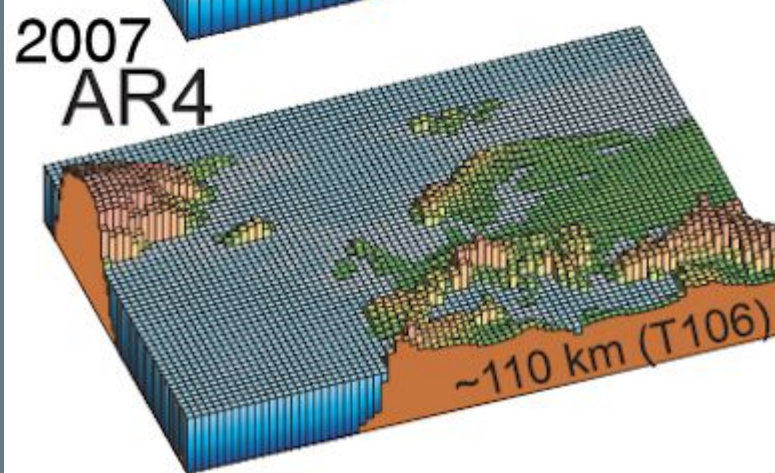$e = E/G =$ energy intensity of economy
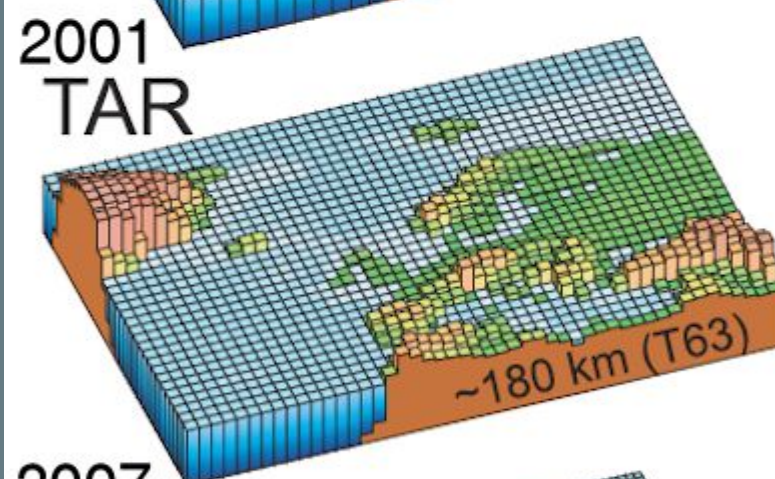
$f = F/E = CO_2$ intensity of energy supply

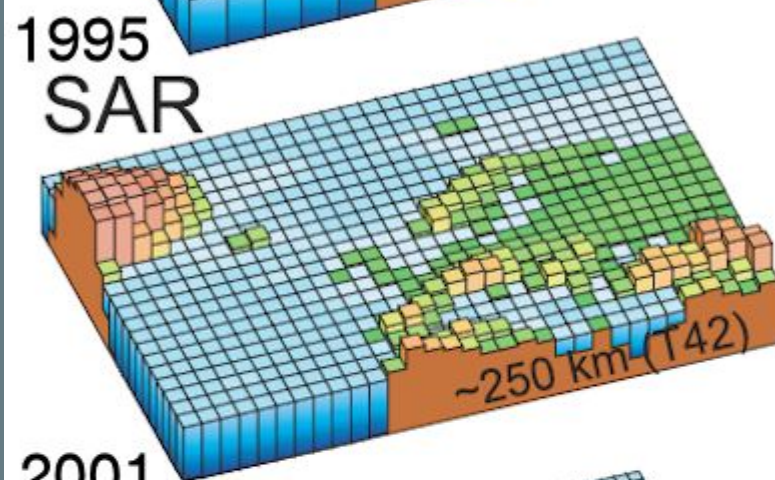# Kaya Identity in Practice

Computer Models of Climate

Computer Models of Climate

Computer Models

Computer Models

1990 FAR ~500 km (T21)
1995 SAR ~250 km (T42)
2001 TAR ~180 km (T63)
2007 AR4 ~110 km (T106)

AR5 (2013) 87.5 km x 87.5 km

Next Generation 30.0 km x 30.0 km
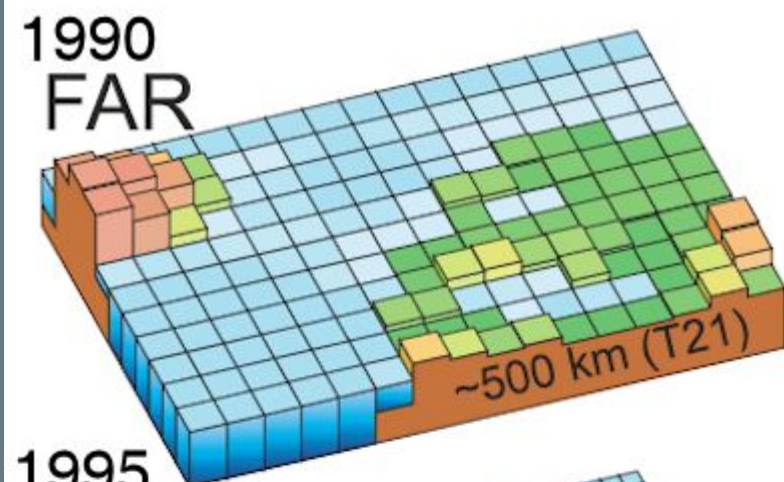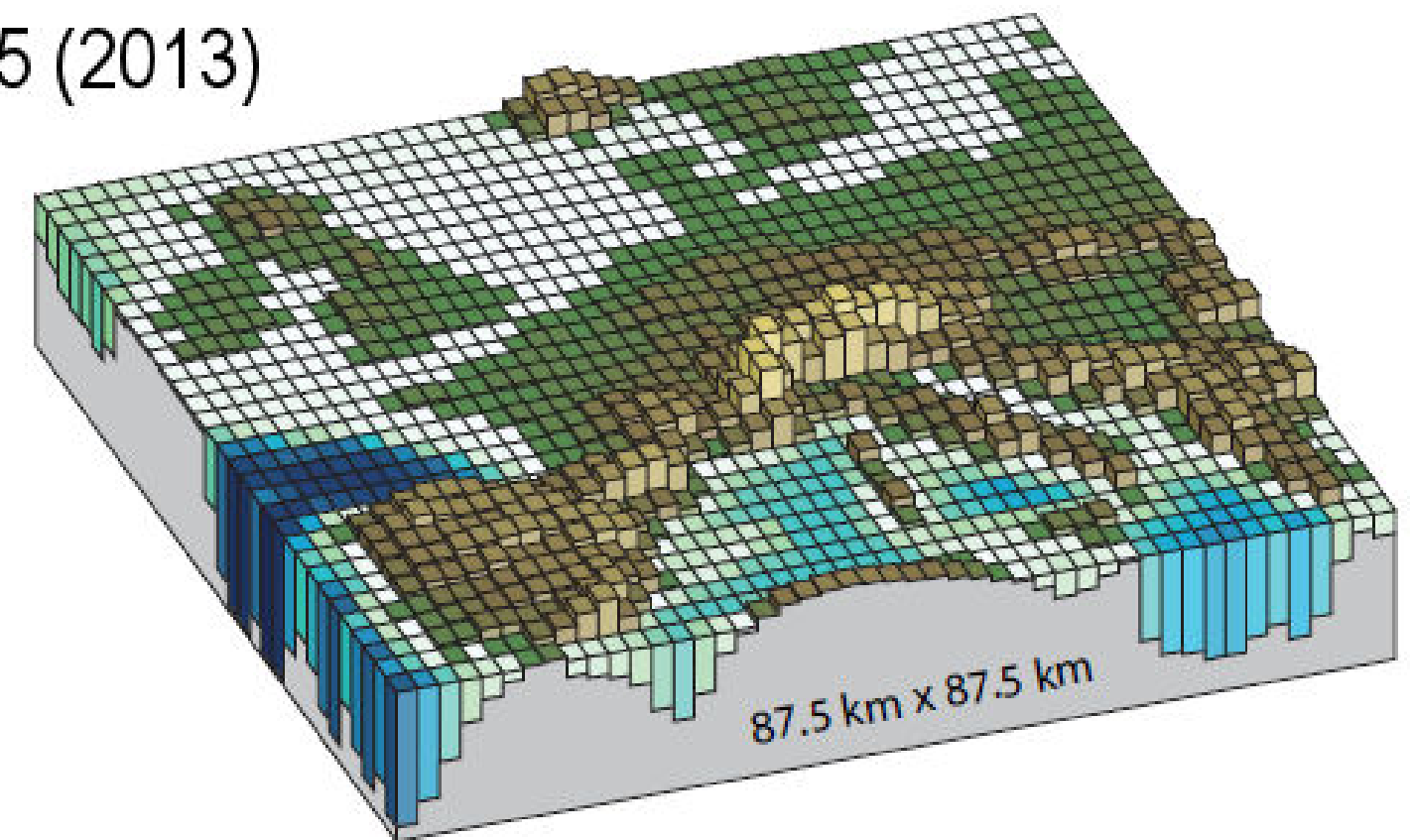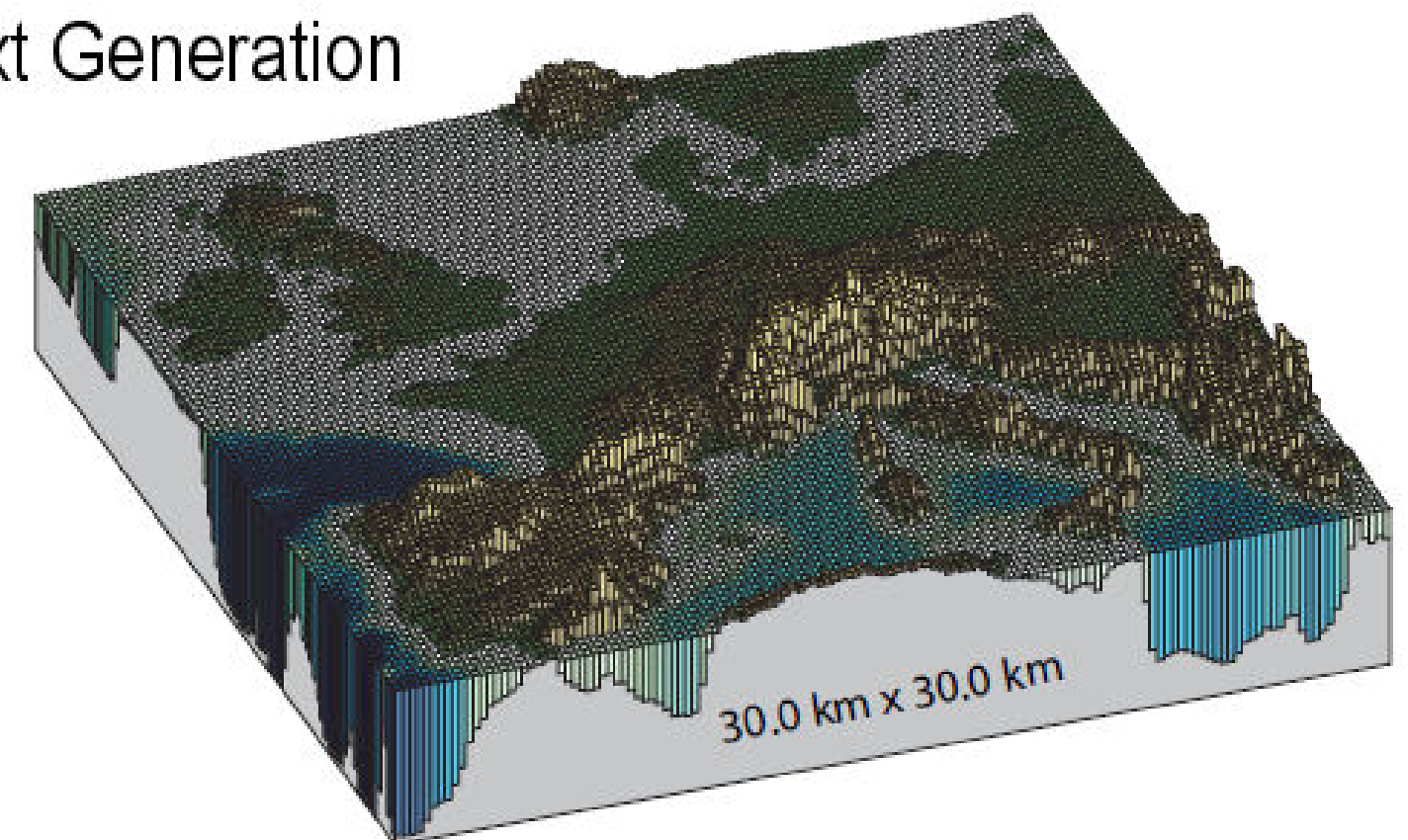
Principles of Computer Modeling

- Make models as simple as possible:
  - Start simple
  - Add complexity only as needed
    - Different models for different purposes
  - Check model against real world

"Things should be made as simple as possible, but no simpler."

-- Albert Einstein
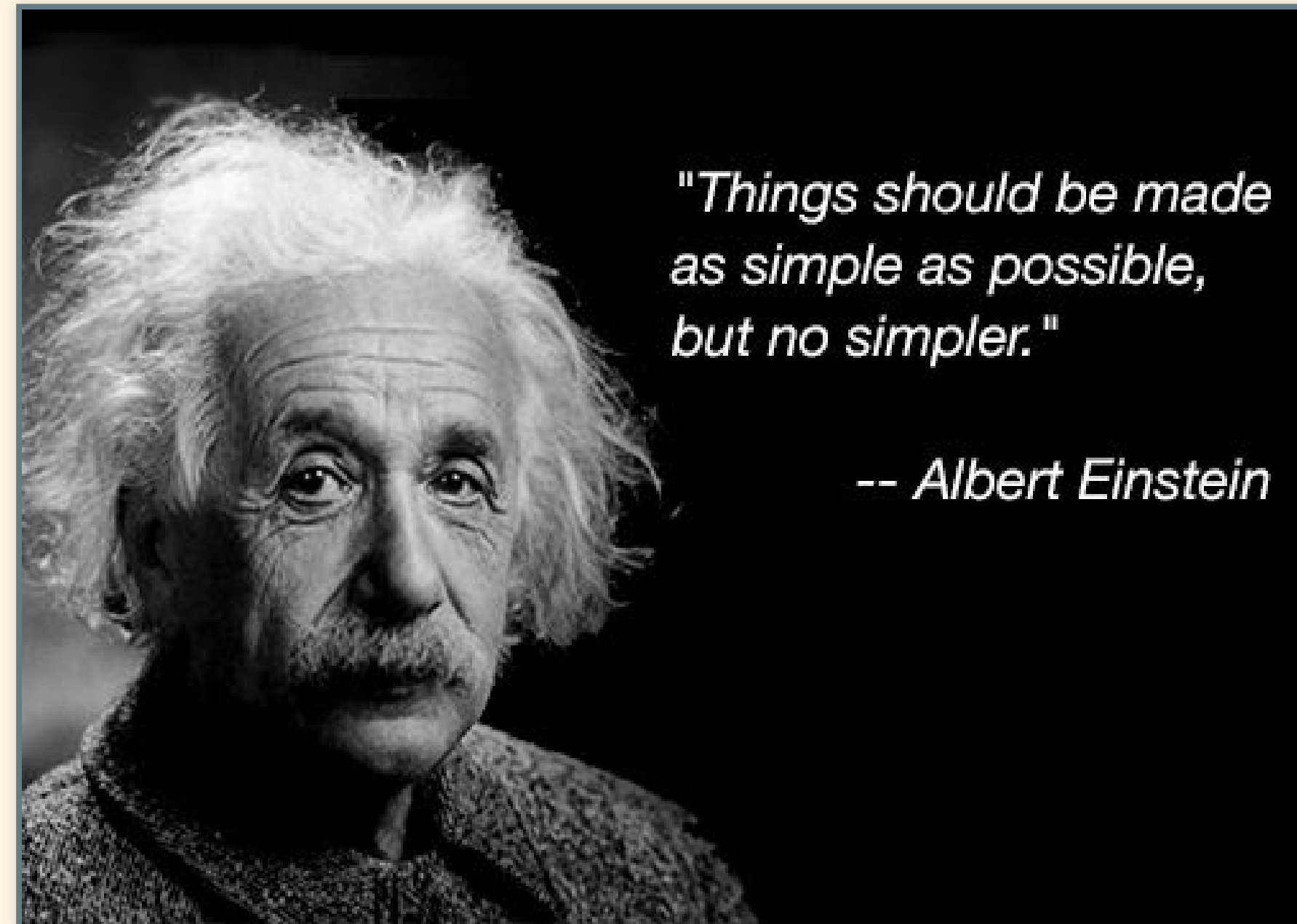
Transient vs. Equilibrium Response

Transient vs. Equilibrium Response

- Gradually raise CO_2 and then stop.
- Planet takes time to heat up
  - Oceans absorb heat
  - Like pot of water on stove
- Transient response:
  ΔT when CO_2 stops changing
- Equilibrium response:
  Stable temperature (much later)
  - Green: Atmosphere & surface ocean
  - Red: Atmosphere, surface ocean, & deep ocean.
- Equilibrium takes many decades.
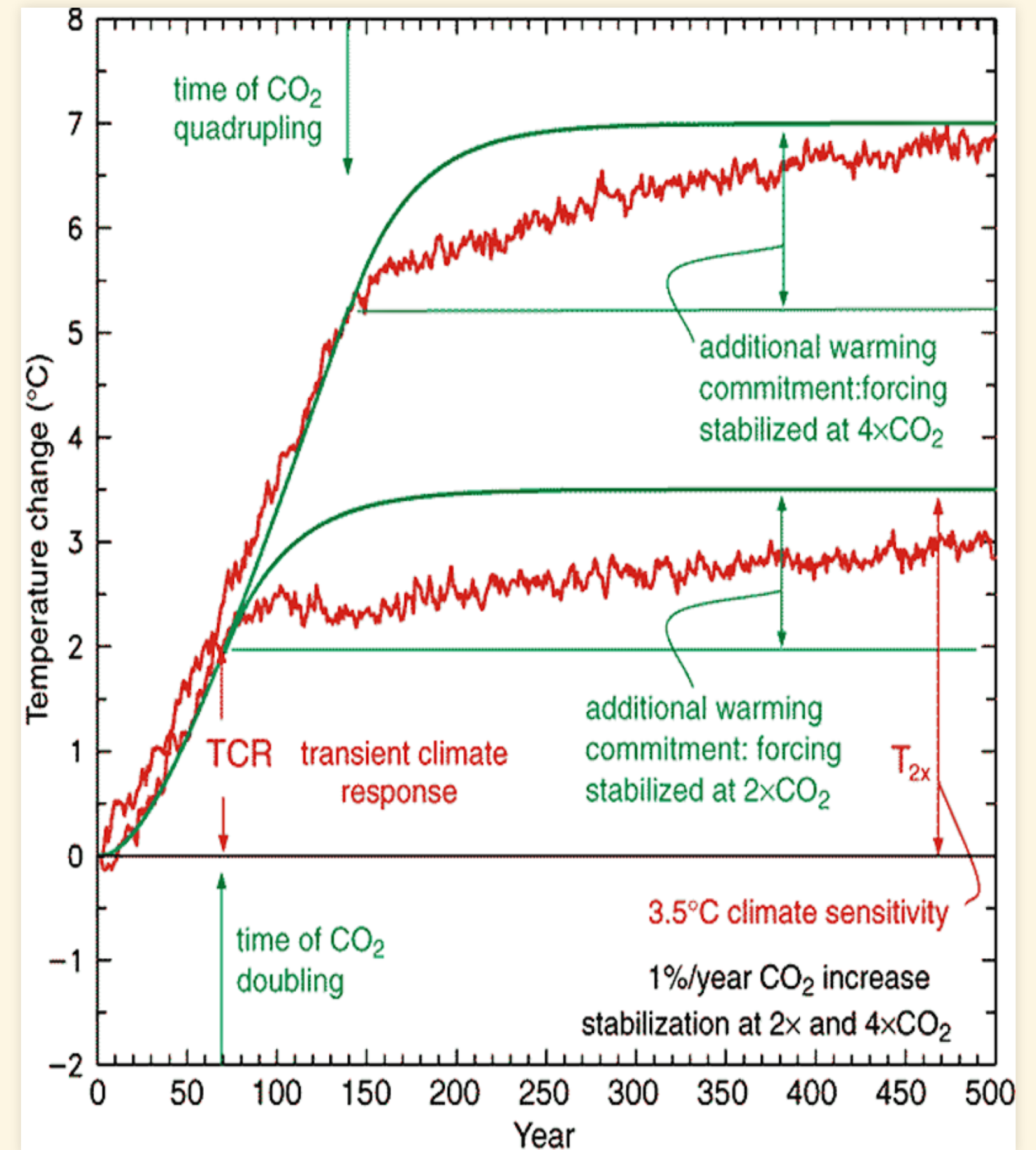
Modeling for Science vs. Policy

Modeling for Science vs. Policy
Integrated Assessment Models (IAMS)

- Combine climate system and world economy
  - Emissions as a consequence of economic activity
    - Energy use for production (factories, etc.)
    - Energy use for consumption (households, etc.)
    - Farming: fertilizers, livestock, paddy fields, etc.
  - Climatic impacts on economy
    - Cost of severe weather
    - Sea level rise
    - Droughts & heat waves
    - ...
- **Optimize for greatest net economic output**

Climate Projections

- Biggest uncertainty in predicting future climates is GHG emissions
  - We can predict consequences of emissions
  - We can't predict what emissions will be
- Scenarios and Pathways:
  - **Scenario**: possible future,
    - Story of economic & political development → resulting emissions
  - **Pathway**: possible future,
    - Trajectory of emissions → economic activity that might cause them
- Projections:
  - Conditional predictions:
    - "**If** emissions do this, **then** climate will do that."

Projections for future emissions in US:

	2010	2050	Growth rate
g ($/person)	42,300	83,495	1.7%
ef (tons/$million)	432	228	-1.6%
P (millions)	309	393	0.6%
Total Emissions F (million tons CO_2)	**5,647**	**7,471**	1.7 - 1.6 + 0.6 = **0.7%**

Projections for future world emissions:

	2010	2050	Growth rate
g ($/person)	9,780	22,654	2.1%
ef (tons/$million)	522	275	-1.6%
P (millions)	6,410	9,188	0.9%
Total Emissions *F* (million tons CO_2)	**32,724**	**57,289**	2.1 - 1.6 + 0.9 = **1.4%**

Uncertainties in Projections

Projections for future world emissions:

	2010	2050	2100	Growth rate
g ($/person)	9,780	22,654	64,737	2.1%
ef (tons/$million)	522	275	124	-1.6%
P (millions)	6,410	9,188	14,409	0.9%
Total Emissions F (million tons CO_2)	**32,724**	**57,289**	**115,366**	**1.4%**

Uncertainties in Projections

Projections for future world emissions with slightly different growth rates:

	2010	2050	2100	Growth rate
g ($/person)	9,780	24,541	77,505	2.3%
ef (tons/$million)	522	298	148	-1.4%
P (millions)	6,410	9,563	15,766	1.0%
Total Emissions *F* (million tons CO_2)	**32,724**	**69,973**	**180,930**	**1.9%**
Difference		**12,684**	**65,564**	**0.5%**
Difference (%)		**22%**	**57%**	